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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

AUTOMOTIVE HYDRAULIC TRANSMISSIONS

THE WHITE HYDRO-TORQUE DRIVE

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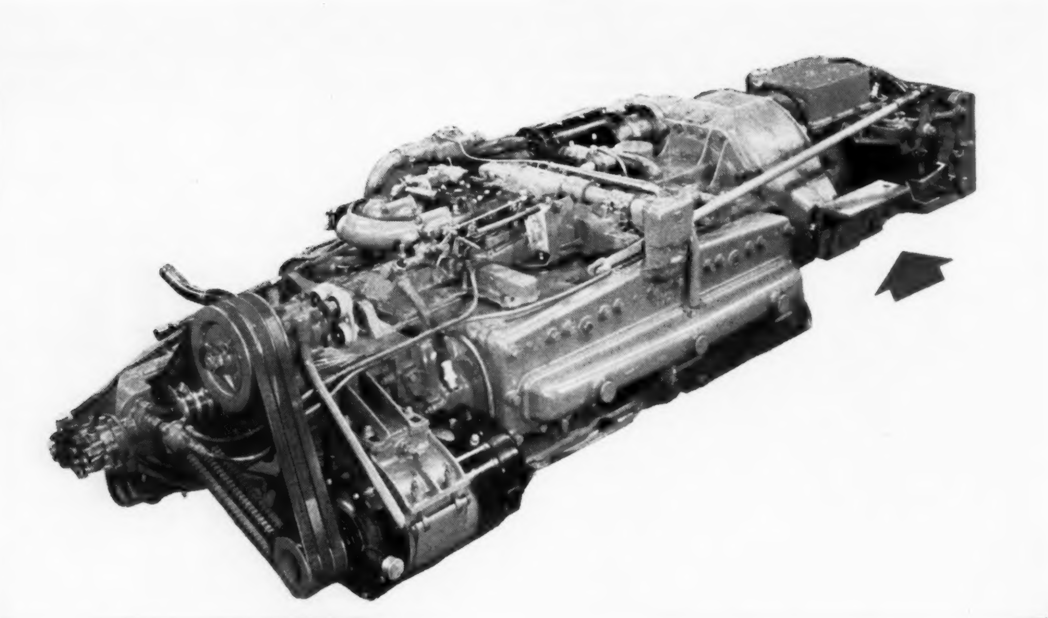

LUBRICATION

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Automotive Hydraulic Transmissions

THE WHITE HYDRO-TORQUE DRIVE

THIS article is the fourth of a series[1,2,3] which describe the development, application, and lubrication of those American Automotive Hydraulic Transmissions that are in current commercial usage.

The White Hydro-Torque Drive is a highly ingenious though relatively simple combination of a fluid coupling, a single stage hydrokinetic torque converter and an automatic two-speed syncromesh transmission. While previous articles have presented a detailed discussion, of the general theory underlying these separate mechanisms, a brief review is desirable in order to fully appreciate the unique logic which exists in a combination of them.

It may be recalled[1,2] that since a fluid coupling contains no reaction blading it can neither increase nor decrease the torque applied to it; in other words it merely transmits torque. The fluid coupling is highly efficient in transmitting torque whenever the output-input shaft speed ratio is close to 1; as the speed ratio is decreased however, the coupling acts more and more like a slipping clutch in that it transmits the applied torque less efficiently. When properly used in an automotive vehicle this latter characteristic is highly advantageous since the slipping clutch action permits the engine speed to increase quickly and smoothly to the point where it is exerting its maximum torque on the coupling. In summary, the fluid coupling is very convenient and efficient both as a clutch and as a coupling, but is incapable alone of acting as a transmission because it can not multiply torque. Figure 1 illustrates these general characteristics.

In effect, the stationary reaction blades of a hydrokinetic torque converter[3] act like lever fulcrums and thereby permit the converter to convert or multiply the torque exerted upon it. The amount of torque multiplication, or torque ratio is dependent upon the number of stages in the converter, the angle, curvature and design of the blading, and particularly upon the output-input speed ratio. As illustrated in Figure 2, the torque ratio is at a maximum when the speed ratio is zero (generally described as "stall condition") but decreases as the speed ratio increases until at the so-called "clutch point"[4] the output torque just equals the input. Maximum efficiency of a high order is obtained just before the clutch point, but the efficiency curve drops precipitously if operation at speed ratios beyond the clutch point is attempted. Very high torque ratios under stall conditions can be obtained by increasing stages and otherwise modifying the design but the general result is a decrease in maximum efficiency, and a decrease in the clutch point speed with resultant decrease in the usable speed range of the converter.

A re-examination of Figures 1 and 2 will show that the characteristics of the fluid coupling and

[1] LUBRICATION—Nov. 1946—Automotive Hydraulic Transmissions.
[2] LUBRICATION—April 1947—The Hydra-Matic Transmission.
[3] LUBRICATION—Nov. 1947—The Hydrokinetic Torque Converter.
[4] The reader is reminded that "clutch point" is a term used to designate that condition in a Hydrokinetic Torque Converter when the output torque exactly equals the input (or the torque ratio equals one). The term is used without regard to the presence or absence of an auxiliary mechanical clutch.

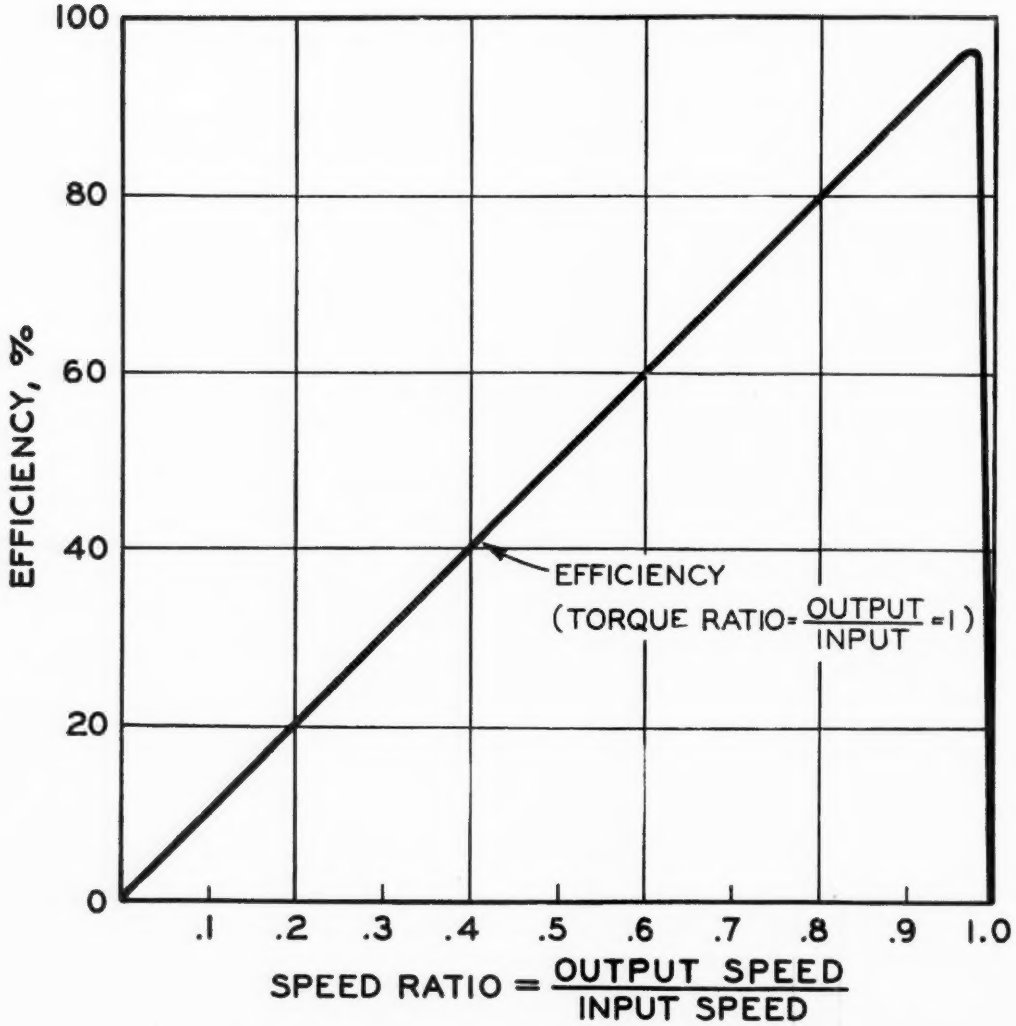

FIGURE 1 — GENERAL CHARACTERISTICS OF A FLUID COUPLING

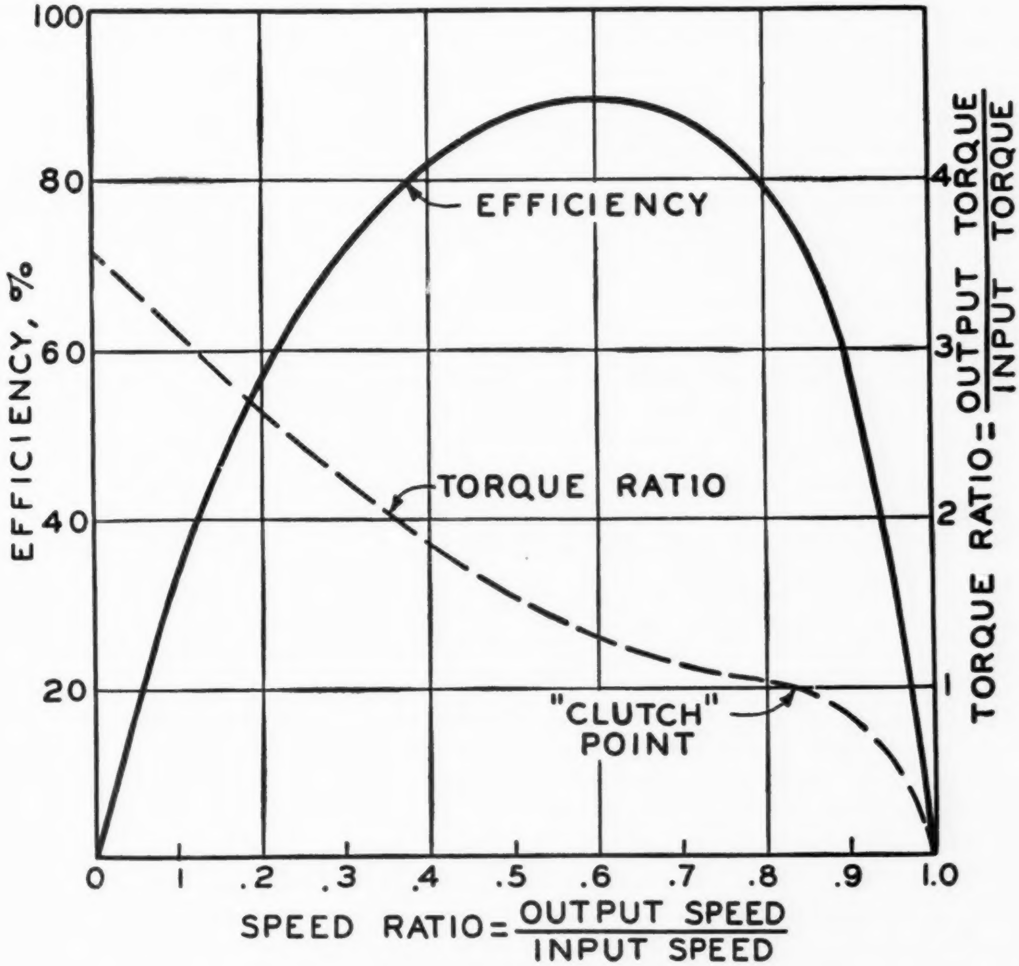

FIGURE 2 – GENERAL CHARACTERISTICS OF A SINGLE–STAGE HYDROKINETIC TORQUE CONVERTER.

torque converter are complementary to each other; i.e. one is most capable when the other is least. For example, the converter powerfully multiplies applied torque at low speed ratios whereas the coupling can only transmit the applied torque. However, at high speed ratios the fluid coupling transmits torque at high efficiency whereas the converter falls down miserably. The possibility and desirability of combining the characteristics of a coupling and a converter are self-evident.

Early designers[5] correctly deduced that the real cause of a converter's sudden deficiency above its "clutch point" must be due to an abrupt and undesirable change in the fluid flow from pump blading through the reaction blading to the turbine. In other words, at the clutch point the pump and turbine blading of the converter are moving at very nearly the same speed and in the same direction, consequently an orderly transfer of fluid between them should be possible. But interposed between the pump and turbine blading we have a rigid and uncompromising stationary set of reaction blades which are now placed angularly across the line of fluid flow, and thereby interfere by causing chaotic, turbulent (and therefore inefficient) fluid flow. Actually, under this condition the fluid from the pump impinges against the *back* sides of the reaction blading! If some way could be devised to remove or at least isolate the reaction blading in a converter, preferably by automatic means, we would obtain the highly desirable combination of a fluid coupling and hydrokinetic torque converter. As will be seen this combination is accomplished most ingeniously and simply in the White Hydro-Torque.

Figure 4 illustrates the principal elements of the combination single stage converter and fluid coupling used in the White Hydro-Torque Drive, together with the auxiliary transmission which we will ignore for the time being. The converter-coupling consists of the usual pump which is bolted to the cover and driven through the coupling gear by the engine. Enclosed within the pump-cover assembly is the output turbine which is splined to and drives the main drive gear assembly. Enclosed within and between the pump and turbine but entirely separate from them is the reaction member. Figure 5 illustrates the assembly and testifies to its unique compactness. For the moment, however, primary attention is invited to Figure 4 and to the reaction member which is at least the heart and half of the brain of the converter-coupling. The reaction member is a precision aluminum casting which incorporates the single set of reaction blading, the whole being mounted on the outer race of a sprag type one-way clutch or free-wheel unit. The inner stationary race of the one-way clutch, and of course the reaction member, are supported on the stationary hollow reaction sleeve assembly. In other words, this ingenious application of a free wheel unit permits the reaction member to furnish reaction only when reaction is required, and otherwise permits the reaction member to freely rotate in the same direction and speed as the converter output turbine. Simply stated, the free wheel device in the reaction member is responsible for the abilities of the whole device to operate either as a converter or fluid coupling, and to transfer smoothly and wholly automatically from converter to coupling operation (and vice versa) in complete and sensitive response to the vehicle's torque requirement. Referring over to Figure 3, the combination converter-coupling operates wholly as a single stage converter when the speed ratio is below the clutch point. As soon as the clutch point is reached reaction forces on the reaction stage become zero, the reaction member is released to rotate with the turbine and the whole device thereby becomes an efficient fluid coupling.

[5]Heinrich and Adolph Schneider, et al.

Referring again to Figure 3, it will be noted that the practical maximum torque ratio of a single stage converter is about 3.6 which is neither sufficient in itself to start and accelerate a heavy vehicle, nor to propel it up a steep grade. For example, it will be recalled[3] that other commercial converters are of the three-stage type which ordinarily have a torque ratio of almost 6. However, the avoidance of mechanical complications as well as other considerations dictate the use of only a single stage if a converter is to be combined with a fluid coupling, consequently some auxiliary torque multiplying device such as an automatic two speed gear set is required.

Figure 6 illustrates the results obtained from a well designed combination of a converter, fluid coupling and automatic two speed gear set. It will be noted that these curves are actually a doubling-up of those presented in Figure 3 since the converter-coupling operates similarly regardless of whether the auxiliary gear set is in low or high speed position. These curves have been meticulously plotted to show the slight variations that are indicative of the cooperation between the three major elements of such a transmission: during actual operation in the vehicle these variations are too minor to be detectable. For example, the transmission illustrated in Figure 4 is designed to effect a gear shift at a vehicle speed of 25 miles per hour. Starting from a standing stop (the gear set being in low gear), we obtain the unusually high torque ratio of 7.5 which of course, represents the converter torque ratio of 3.6 multiplied about twice, (actually 1.982) by the gear set. At the same time, the efficiency curve rises abruptly to a high level which is sustained thereafter. As the vehicle ac-

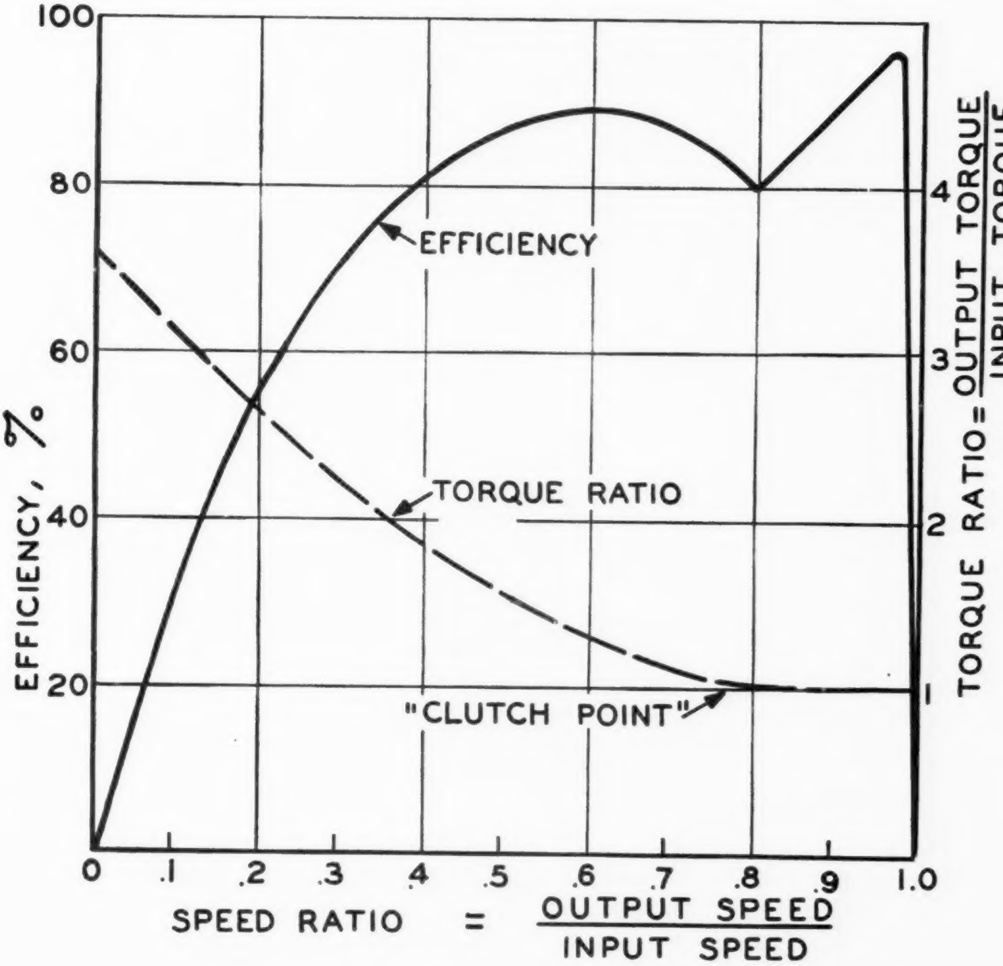

FIGURE 3 - GENERAL CHARACTERISTICS OF A COMBINED FLUID COUPLING AND SINGLE-STAGE HYDROKINETIC TORQUE CONVERTER.

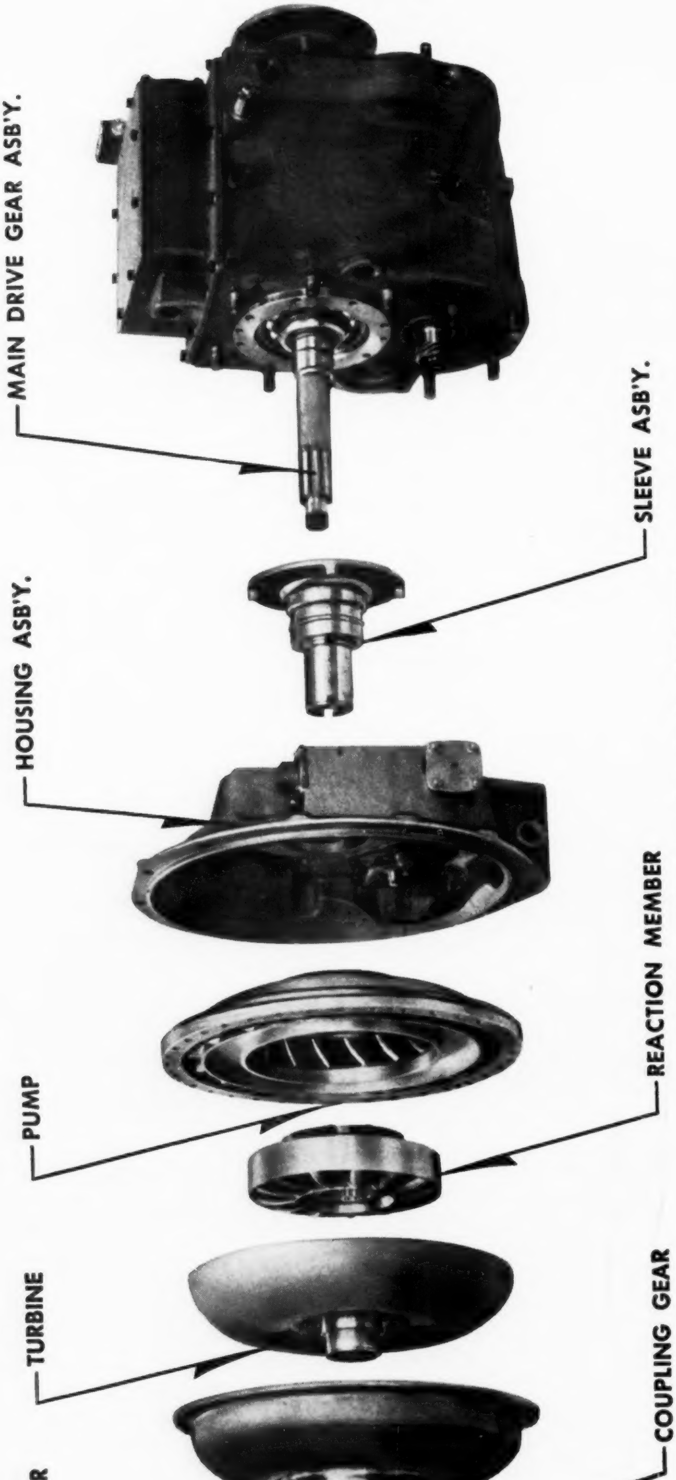

Figure 4 — Hydro-Torque Converter-Coupling Elements.

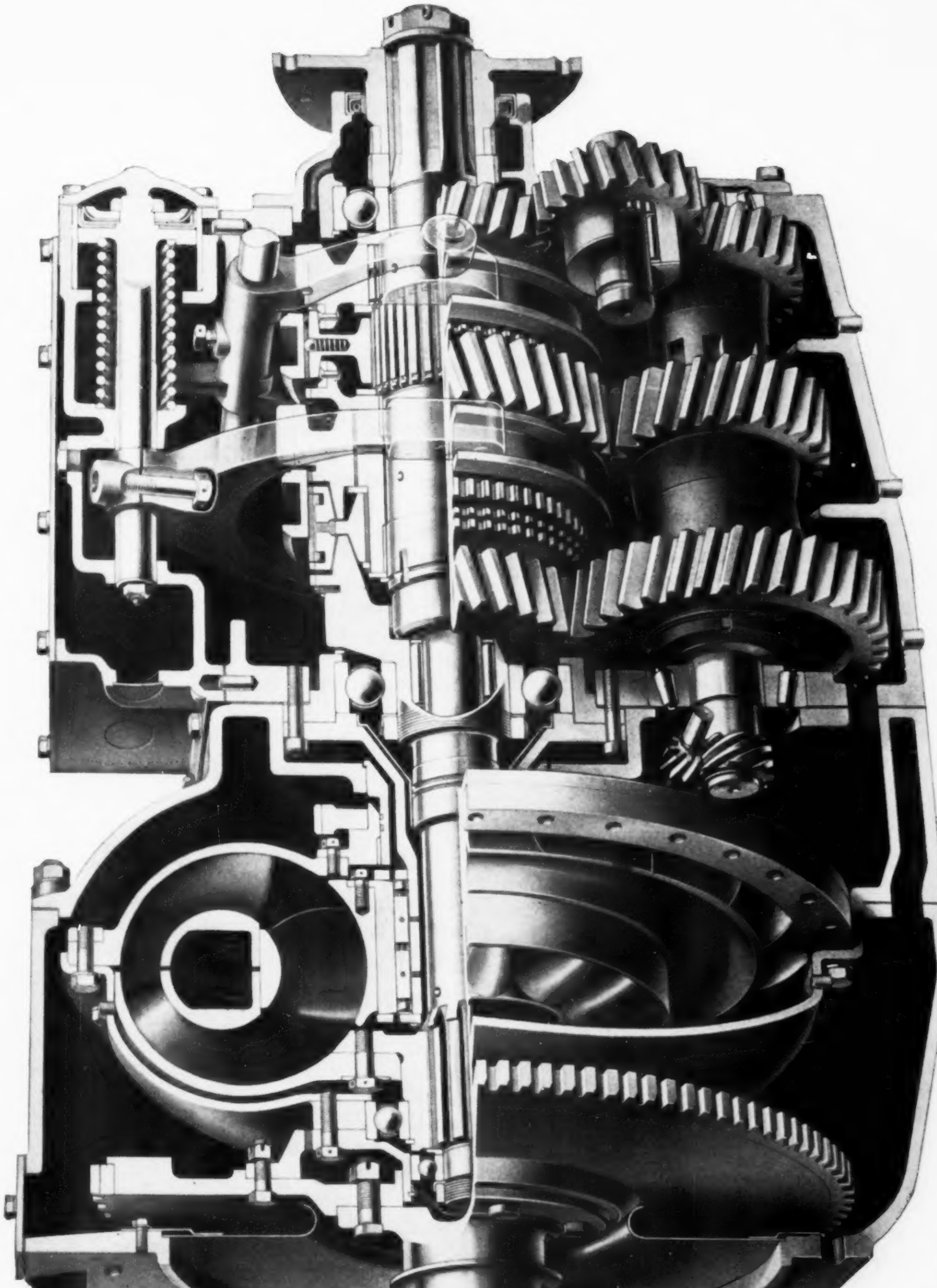

Figure 5 — White Hydro-Torque Drive.

celerates, its torque requirements diminish and the converter ideally and automatically furnishes decreasing torque at increasing output speeds. When the clutch point is attained (at 16 mph in Figure 6 or at a speed ratio of 0.83 in Figure 5) the converter transfers to fluid coupling operation and thereafter transmits engine torque unchanged. With continued acceleration the output-input speed ratio approaches a value of one (at 25 mph, Figure 6) and thereby provides the most advantageous condition to accomplish a shift to the high or direct gear speed of the two speed transmission. At this moment, and because of the increased *vehicle* torque requirement, the reaction member of the converter-coupling comes to a stop and the coupling again becomes a converter. Since the output-input speed ratio is now quite high, the converter operates very efficiently but briefly to again attain its clutch point (at 32 mph) and consequent transfer to fluid coupling operation at all higher speeds.

Reverting to Figure 5, it will be readily seen that the Hydro-Torque's two speed transmission comprises the conventional mainshaft, countershaft, reverse idler shaft, three sets of helical gears and two syncromesh shift units. The two left hand sets of gears provide low and direct forward speeds respectively by shifting the syncromesh unit. (In Figure 5 the first syncromesh unit is engaged with the central mainshaft gear, locking it to the mainshaft, and thereby providing low gear.) The syncromesh unit itself is controlled through its shifter fork by an air cylinder and spring so arranged that the transmission will remain in low gear until air under pressure of about 55 pounds per square inch is admitted by the "high magnet valve" to compress the spring. Control of this unit is vested in the governor system and is automatic. The second or right hand syncromesh unit, however, is shifted manually by the vehicle operator to either its forward speed, neutral, or reverse speed positions. Since there are no free wheeling units in any gear train, the transmission is always "in gear" and the engine is readily and effectively usable as a brake when decelerating or descending grades.

Mention has been made that the converter's reaction member constitutes half of the brain in the White Hydro-Torque Drive: the other half is certainly the electro-pneumatic system which controls the high-low transmission shift. The nerve center of this system is represented by a unique differential type governor that is responsive to both speed and torque, and therefore worthy of closer examination.

Close readers have already noticed that the curves in Figures 1, 2 and 3 were all plotted against the common parameter of speed ratio and have correctly inferred that this ratio must therefore be of major importance in defining the characteristics of torque converters and fluid couplings. In other words the *relative* speeds of the pump and turbine and not their *actual* speeds are of importance, hence the ordinary speed-sensitive type of governor can not be used directly. Although a simple mechanical system to measure speed *ratio* is unknown, the common differential gear as used in our vehicle axles is capable of measuring speed *difference* which closely and quite simply approximates our requirement.

In the miniature differential of the White governor, one differential pinion is driven by the converter turbine through the small pair of spiral gears on the forward end of the transmission countershaft as shown in Figure 5. The opposite differential gear is used to drive the governor. The intervening single spider gear (which meshes, of course, with both differential pinions) is driven by the engine—converter pump system. The governor itself is of the fly-ball type but contains two separate weights each of which operates to snap open or close a pair of electrical contact points. The low speed governor is of similar construction and appearance but is located at the rear of the gear box and driven solely at a speed proportional to that of the vehicle: among its most important functions is to collaborate with the differential governor to establish a minimum *vehicle* speed for shifting.

The last major control component within the transmission itself is the High-Low switch, located on top of the gear box and very positively synchronized with the high-low shift through mechanical connection to the high-low shift fork shaft. The high-low switch contains six pairs of electrical contacts which are opened and closed in a predetermined sequence that is built into the switch.

The physical relationship of the Hydro-Torque to the engine and to all external elements of the control system are detailed in Figure 7. Figure 8 presents a detailed diagram of the wiring circuit. While a study of these figures will provide a general knowledge of the control system our research-minded readers are advised to consult the manufacturer's maintenance manual for intimate details and an excellent step-by-step description of the operation of the control system. Some of the more obvious advantages of the system are as follows:

a. The vehicle operator is relieved of all gear shifting and can, therefore, devote more attention to safety precautions, fare collections, and, improved public relations.

b. Whenever convenient, such as when descending a very steep hill, the operator can cause the transmission to remain in either low or high gear by merely flipping the overrule switch.

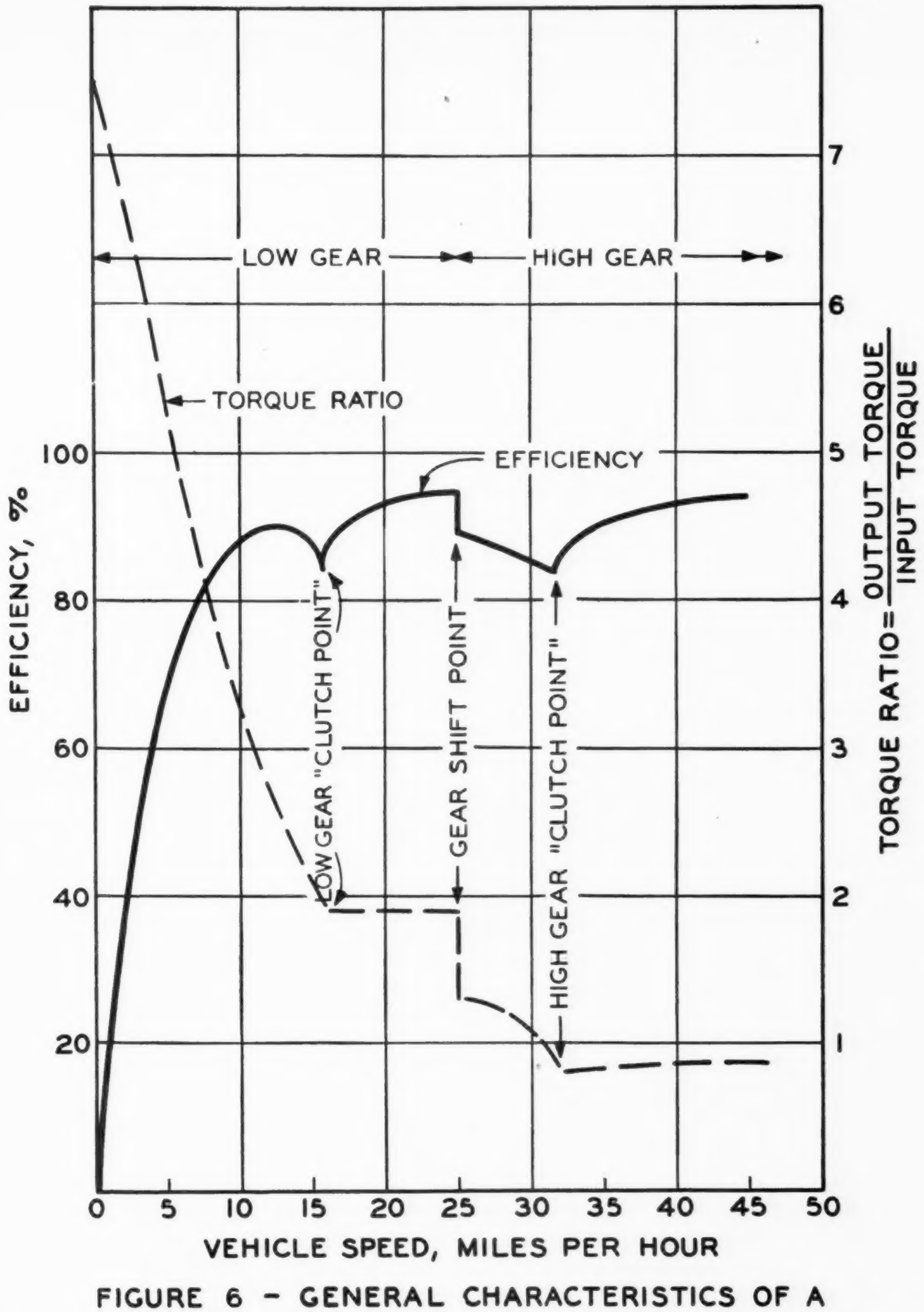

FIGURE 6 – GENERAL CHARACTERISTICS OF A COMBINED FLUID COUPLING, SINGLE-STAGE HYDROKINETIC TORQUE CONVERTER AND TWO-SPEED AUTOMATIC GEAR SET.

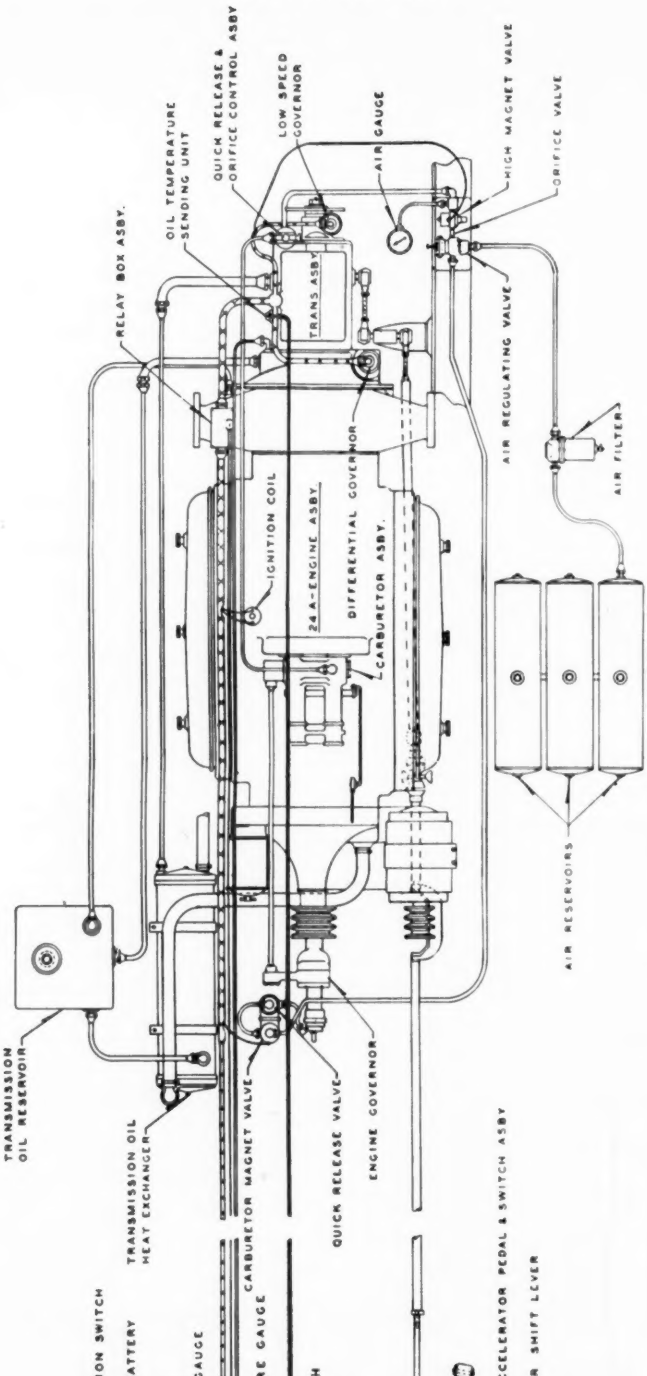

Figure 7 — Hydro-Torque Drive Control Layout.

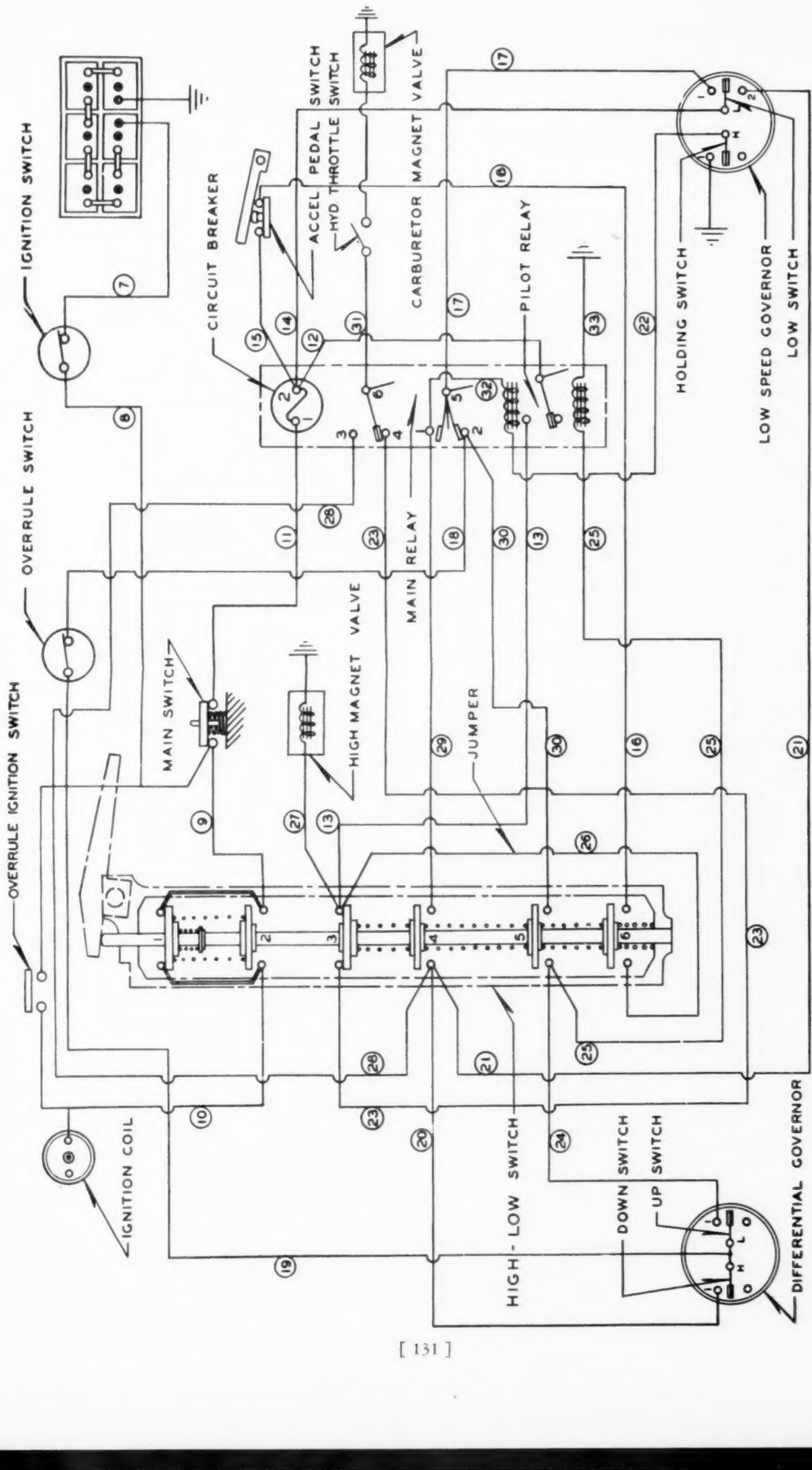

Figure 8 — Hydro-Torque Wiring Circuit Diagram.

c. The vehicle operates in hydraulic drive (either converter or fluid coupling) at all times with resultant smoothness of operation and excellent passenger comfort.

d. Even with a dead storage battery, the vehicle engine is readily started by merely pushing the vehicle.

e. Without the necessity for any attention from the vehicle operator, the torque responsive control system automatically provides for the best obtainable acceleration and economy under any prevailing conditions of load, road resistance, speed and throttle opening.

Lubrication

Perhaps the most distinctive feature of the Hydro-Torque's lubrication system is that the same lubricant is circulated through and used by both the torque converter and the gear box. Among other advantages, this construction avoids the necessity for converter oil seals which are difficult to maintain and replace.

The converter housing contains a dual type pressure and scavenger oil pump of the rotor type which is geared to the converter pump assembly and therefore positively driven by the engine. The suction line of the pressure pump is connected through a filter to the external oil reservoir Figure 7; the pump discharges oil under a pressure of between 30 and 40 pounds into the converter by means of a channel between the reaction member sleeve and converter housing. A portion of the oil in the converter is allowed to escape through a passage between the reaction sleeve and turbine shaft to a pressure relief valve which discharges through a passage in the housing to the inlet of the scavenger pump. The remainder of the converter's excess oil enters a radial hole in the turbine shaft Figure 5 and thence through the axial hole in the shaft to other radial holes underneath the bearings and syncromesh units of the gear box. The floor of the gear box is baffled to retain a predetermined oil level in dip troughs for the countershaft gears: excess oil flows through a passage into an oil sump in the bottom of the converter housing whence it enters the scavenger pump intake. By this means the converter is not only kept full of oil under pressure, but all moving parts of the gear box are adequately lubricated.

Since complete sealing of the converter is both unnecessary and undesirable, the single seal between the rear pump flange and the converter housing is of the simple and rugged "double piston ring" type. The small amount of oil that leaks through this seal serves to lubricate the drive gears of the oil pump and differential governor as it drains to the oil sump on the floor of the converter housing and is picked up by the scavenger pump. The scavenger pump discharges through a fine screen into the heat exchanger and thence into the external oil reservoir. Since the heat exchanger is supplied with water from the engine's cooling system, it not only restricts oil temperatures to about 270° F. but it also accelerates the attainment of an equable oil temperature during warm-up operation in cold weather.

Since the lubricant in the Hydro-Torque drive is used for a number of purposes it must possess a well balanced combination of several properties such as the following:

a. In its capacity as a torque fluid and heat exchange media it should have minimum viscosity consistent with other requirements, avoidance of foaming, a reasonably low pour point, excellent oxidation stability, and avoidance of any deleterious effects such as varnish or sludge either on or through contact with aluminum, steel, copper and bronze.

b. As a gear lubricant, the oil must furnish adequate anti-scuff protection to steel helical, spur and bevel gears, and should promote ease of engagement and long life of the syncromesh units.

c. The oil must lubricate a variety of plain and anti-friction bearings and thrust washers, and must provide a reasonable degree of protection against rust.

d. For practical reasons the oil should be widely distributed, readily obtainable, usable for a considerable period.

As a consequence of extensive experience and controlled field tests, the manufacturer of the Hydro-Torque now recommends the use of heavy duty type engine oils which are qualified under U. S. Army Specification 2-104B and which meet certain additional requirements. The SAE 20 viscosity range is suggested for summer use and the SAE 10 for winter. A maximum drain period of 12,000 miles is recommended in normal service and the entire system holds approximately nine gallons if the desirable precaution is taken of draining the converter.

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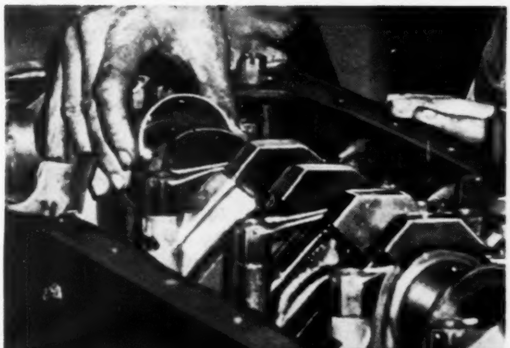

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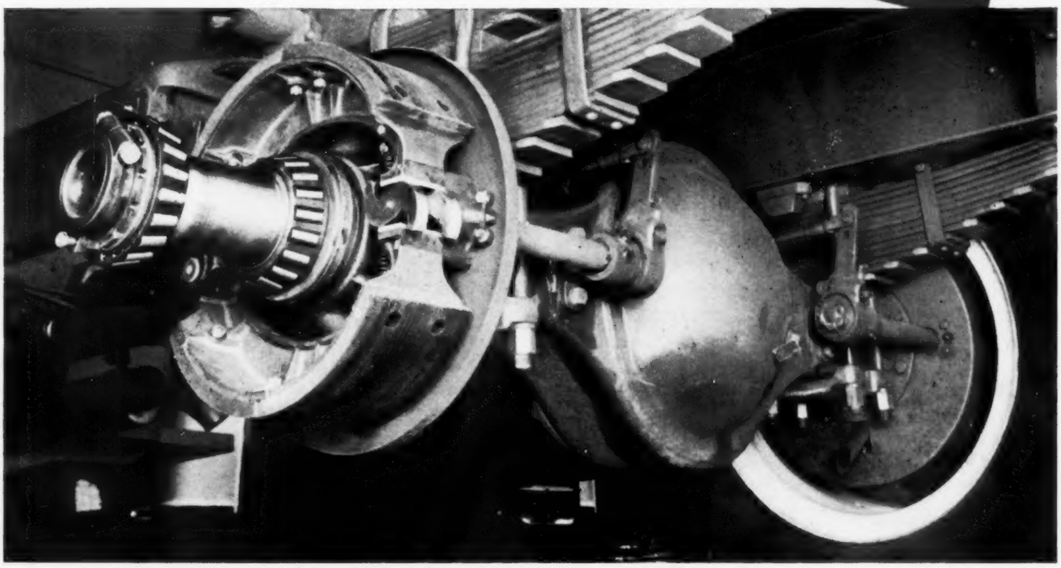

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